SOUND INSULATION TESTING ON SITE - ISO 140 AND THE ANC GOOD PRACTICE GUIDE.

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1 INTRODUCTION

In 2002 it became clear that pre-completion testing for dwellings would be mandatory under changes to the Building Regulations, and that Approved Document E would require testers to have UKAS accreditation or an equivalent alternative. It also became clear that a very large increase in the number of accredited testers would be required to meet the demand for tests. After discussions with UKAS and the ODPM, the Association of Noise Consultants therefore set up an equivalent alternative to UKAS accreditation, and the "ANC Registration Scheme" received government approval in 2003. At the time of writing the scheme has processed more than 60,000 tests by registered ANC testers. The results are held centrally, giving a unique and vast database of test results for statistical analysis.

A common misconception (particularly in local authority building control) is that membership of the ANC automatically qualifies a company to undertake pre-completion testing. This is not the case and the ANC imposes stringent requirements for registration, checking and annual audits. Logistical aspects of the scheme are described elsewhere [1] and a separate paper at this conference [2] describes the results of the ANC's recent "Round-Robin" tests to establish the repeatability of test results. At the time of writing (March 2007) a further joint research project between the ANC, Robust Details Ltd and Building Research establishment was in progress to investigate uncertainties and variations as a result of different measurement techniques.

This paper addresses broad technical issues arising from this experience and from our review of BS EN ISO 140 Parts 4 and 7. The ANC found that important aspects of these standards were open to different interpretations and is therefore issuing a Good Practice Guide to address these problems. The Guide addresses matters such as averaging of results, loudspeaker types, microphone configurations, room modes and reverberation time measurements are all discussed.

It is hoped that the Guide, and the research behind it, will influence changes to technical aspects of the standards, as well as to a review of the way in which the standards for acoustic measurements on site are drafted, revised and implemented.

The Good Practice Guide and the Scheme on which it is based are the result of work by the Board, Examiners and Members of the Association of Noise Consultants' Registration Committee. In this paper the terms "we" and "us" are used informally to refer to these bodies, of which the author is a member. This paper is not, however, published on behalf of the Association and the views expressed herein are those of the author alone.

2 ABBREVIATIONS AND NOMENCLATURE

A number of abbreviations and acronyms are used in this paper and for ease of reference, particularly for readers from outside the UK, these are explained below.

ANC Association of Noise Consultants, the UK's professional body for acoustic consultants (the Institute of Acoustics represents all acousticians whether consultants or not).

DCLG Department of Communities and Local Government, which administers building regulations in England and Wales. Previously called ODPM.

ADE Approved Document E of the Building Regulations "Resistance to the passage of sound" which sets out guidance and criteria for sound insulation between dwellings in England and Wales. In this context we refer to the 2003 edition which for the first time requires pre-completion testing of sound insulation between dwellings

UKAS United Kingdom Accreditation Service.

PCT Pre-completion testing – i.e. airborne and impact sound insulation tests required on new and converted dwellings

RDL Robust Details Ltd, an organization which administers a scheme of Robust Details for new dwellings as an alternative to PCTs. The RDL Inspectorate carries out a stringent regime of inspections and sample tests on Robust Details.

3 THE NEED FOR A GOOD PRACTICE GUIDE

Many people who have been measuring sound insulation for decades have been surprised to find out that in fact their methods do not comply with BS EN ISO 140. Sometimes this arises because measurement methodologies were set in the days of the previous British Standard BS 2750. In a few cases errors have arisen where people have tried to take measurements without the necessary expertise and understanding of sound insulation, and in others – not mutually exclusive from the above – they simply have not read the standards with the necessary care and attention. Many of the queries referred to the ANC's Registration Scheme Committee could have been dealt with by the simple answer "Read the standards".

It has also come as a surprise to many that the proprietary software supplied with their sound level meters does not necessarily comply with either BS EN ISO 140 or Approved Document E. It is perhaps understandable, but not encouraging, that so many acousticians have bought and applied software without checking that it complies with the standards.

It has also become clear, however, that parts of the relevant standards BSEN ISO 140 Parts 4 and 7 are at worst incomplete and at best open to different interpretations. This is not a desirable state of affairs for measurement standards, but is perhaps an inevitable result of the way in which acoustics standards are compiled – that is over a period of many years, by international committees of people with widely different interests, who are not necessarily best acquainted with the day-to-day use of their standards on site. Almost by definition, any standard assembled under such a scheme is likely to be out of date by the time it is published. Standardisation organizations do not necessarily fund research where this is needed to inform their Committees' decisions, and in the case of ISO 140 Parts 4 and 7 it seems that there far less data from site measurements then from laboratories. The site standards were therefore derived largely from experience in the very different conditions met in acoustic laboratories.

Poor standardisation was not such a serious issue under the previous building regulations, as measurement of sound insulation on site was not required. With mandatory pre-completion testing, however, reproducibility of results has become much more important, not least to avoid contractors seeking out consultants whose measurement methods are more likely to result in a “pass” than a “fail” result. Hence the need for a document setting out guidance for consistent interpretations of the standard.

4 PRINCIPLES OF THE GOOD PRACTICE GUIDE

In drawing up the ANC Registration Scheme, a few underlying principles were agreed. It follows that the same principles apply to the Good Practice Guide.

4.1 Ownership

The ANC Scheme has been developed and funded by the Association at considerable cost in members’ time and money. There would be no benefit to members in making this generally available outside the ANC, any more than there would be in UKAS making procedures available to non-UKAS accredited organizations. The ANC Scheme is already being imitated by some non-members who issue certificates bearing a very close resemblance to those issued by the ANC. Making the Guide generally available would assist this process and would lead to claims from non-registered organizations that they measure “…in accordance with the ANC Good Practice Guide”. As we have no control over these non-registered organizations, this would debase both the Guide and the scheme as a whole. The Guide is therefore not intended for publication outside the ANC.

4.2 Compliance with the standards

Compliance with the standards described in Approved Document E is an absolute requirement of the scheme. ADE requires compliance with BS EN ISO 140 Parts 4 and 7, and BS EN ISO 717 Parts 1 and 2, and it follows that the Scheme must comply with these standards. This applies even where, technically, the standards are incorrect (for example in the background noise correction). For PCTs to be meaningful the results have to be, as far as possible, independent of who measures the sound insulation – hence all testers must use the same standards, even if these are flawed. The ANC is also working to help and influence the revision of these standards, but this is a separate (and rather slow) process.

In some respects we believe the standards to be unnecessarily proscriptive – for example, in the requirement for no more than 6 dB between adjacent third-octave band Leqs in the source room, which dates back to the use of meters with analogue filters. None the less, until either the standards or ADE are changed, the scheme must comply with the standards.

In some cases where the ISOs are particularly unclear, Annex B of ADE imposes a specific interpretation. For example, ADE specifies arithmetic averaging of level differences, as discussed later in this paper. For PCTs that supersedes the requirement (or lack of one) in ISO 140. This raises an interesting question for UKAS accreditation ; a practice might have UKAS accreditation to test in accordance with BS EN ISO 140 Parts 4 and 7 while using energy averaging of level differences, and so would not comply with ADE.

In places where the standards are incomplete or ambiguous and are not clarified in ADE, we have interpreted in terms of what the standard states. We consider the argument “..but surely this is what the Committee meant” to be inadmissible in the context of a national or international standard.

A fundamental precept of the Scheme is that the measurement requirements should be no more restrictive than the standards – for example, where the standards allow several methodologies, the Scheme should not impose one of these methodologies at the expense of others. Neither should the scheme try to impose a "Gold standard" in excess of the requirements of the ISO. This may seem self-evident, but it contrasts with UKAS approach accreditation which requires, for example, 12 of 18 reverberation time measurements in normal rooms as opposed to the 6 required in ISO 140 Part 4. The stated justification for this "Gold standard" approach is that each company applying for accreditation is permitted to set out a technical case justifying a reduction in the number of measurements, and that a reduction will be permitted if the UKAS assessor considers the case to be justified. We consider this to be a waste of time as well as contrary to the purpose of standardisation. We have assumed that if the ISO standard considers 6 measurements to be adequate for a site measurement in a normal room, no further justification is needed for a tester to use that number of measurements.

4.3 Practicalities

Pre-completion testing is carried out on site, not in the laboratory. In most cases the work takes place on working building sites, where the greatest threat to accuracy comes from varying and intrusive ambient noise levels. These noises are not random in nature – for example, there may be only a short time period when a noisy item of plant is not operating. In such cases, it may be more accurate to measure over the shortest period permitted by the standards during a period of low ambient noise, than to extend the measurement period and to have some of one's measurements affected by extraneous noise.

There are also commercial pressures, both on the client and the consultant. Down-time on building sites is expensive, and a contractor will not wish to close down his site for any longer than is necessary. A methodology that takes four hours per set of tests as opposed to two must be justified by a significant and necessary increase in reproducibility. This is a marked contrast to the acoustic laboratory where absolute accuracy is assumed to be paramount.

There are also health and safety issues to consider. On a noisy site, achieving a signal-to-noise ratio of 15 dB rather than 10 dB may require the use of very heavy sound sources, which may have to be manhandled across uneven ground or up stairs. Smaller sources may be perfectly adequate and much safer to handle. The Guidance has to take account of such issues, which are outside the scope of a purely technical standard..

5 TECHNICAL ISSUES

This section addresses some of the more frequently asked questions which are addressed in the Guide. It is not a comprehensive list.

5.1 Loudspeaker types

Section 6.2 of EN ISO 140-4 states
"If the sound source enclosure contains more than one loudspeaker operating simultaneously…it shall be assured…. that the radiation is uniform and omnidirectional, as specified in A.1.3"

Section A.1.3 discusses polyhedral loudspeakers and sets out a procedure for assessing their directivity. The standard does not, however, require polyhedral loudspeakers or preclude the use of other types of loudspeakers. Many testers therefore use cabinet loudspeakers and comparative tests have shown no significant difference in results between the two methods. The Guide therefore allows both polyhedral and cabinet loudspeakers.

5.2 Loudspeaker locations

Section A.2 of EN ISO 140-4 states "*The distance between room boundaries and the source centre shall be not less than 0.5 m*" and "D*ifferent loudspeaker positions shall not be located within same planes parallel to room boundaries*" but does not say by how much the planes must be different. Based on our experience the Guide specifies a difference of at least 100 mm.

Section A.2 directly contradicts the statement in A.1.3 that "*Omnidirectional radiation into the room is also achievable with a hemisphere polyhedron loudspeaker (mounted directly on the floor). Carry out vertical measurements in this case in the direction from the lower room to the upper room*". The Guide therefore allows the use of hemisphere polyhedron loudspeakers mounted directly on the floor for both source positions. For other types of loudspeakers, the centre of the loudspeaker must be at least 0.5 m from the floor for both source positions, with a height difference of at least 100 mm between source positions.

Provided that hemisphere polyhedron loudspeakers are not used, it is clear that airborne sound insulation through floors may be measured either from downstairs to upstairs or from upstairs to down where the rooms are of equal volume. For rooms of unequal volume this choice will be governed by the requirement in B2.15 of ADE , which states that "..*the sound source should be in the larger room*". This is therefore an absolute requirement for PCTs and supports the rather more qualified statement in Section 6.2 of ISO 140-4 that *"If the rooms are of different volumes, the larger one should be chosen as the source room……and no contradictory procedure is agreed upon*".

The casual reader may therefore conclude that a hemisphere polyhedron loudspeaker must not be used for measuring through floors where the room upstairs is significantly larger than that downstairs, because this type of loudspeaker must be mounted directly on the floor. However, A.1.3 does not state that a hemisphere polyhedron loudspeaker must be mounted directly on the floor, but merely that doing so achieves omnidirectional radiation into the room – which is not in itself a requirement. Hence by a strict and logical reading of the standard there is nothing preventing such a speaker from being mounted, for example, on a stand or table, and hence being used for measurement from upstairs to down. There is no evidence that this gives incorrect results.

5.3 Diffusers and room modes

ISO 140-4 states that measurements between empty rooms with identical shape and equal dimensions should preferably be made with diffusers (e.g. furniture or building boards) in each room, and that three or four objects of 1.0 m^2 should be sufficient. We have found that room modes can have significant effects even in rooms of different shapes and volumes, particularly when these are empty and unfurnished. For rooms of typical dimensions, the effect of modes tends to be greatest in the 100 Hz and 125 Hz third-octave bands, and so of course has a disproportionate effect on $D_{nTw}+C_{tr}$. We have found that in rooms with strong modal response, using diffusers can result in an apparent improvement of 7 dB in $D_{nTw}+C_{tr}$ between rooms separated by lightweight cavity masonry walls.

The Guide therefore suggests the use of diffusers in all cases where the tester considers room modes to be significant. This is often indicated by unusually large values of Ctr and by large variations in source and / or receiver room levels, particularly at 100 and 125 Hz. This is justified by the fact that in occupation, rooms will inevitably contain enough absorption and diffusion to attenuate low-frequency room modes. It should be remembered that the calculation procedure in ISO 140 assumes normal reverberant fields and diffuse conditions in accordance with Sabine's law, and the addition of diffusers makes this assumption more realistic.

5.4 Fixed and moving microphones

Section 6.3 of ISO 140:4 allows either for at least five fixed microphone positions, or for moving microphones. The traverse of a moving microphone is defined as having… *" a sweep radius of at least 0.7 m, with a traverse period of at least 15 s and a traverse plane inclined at more than 10 degrees from any plane of the room".* It does not, however, state that this must be achieved by a mechanical rotating boom and many testers do this manually. This has come as a surprise to many testers with a laboratory background, who had assumed that a moving microphone can only be provided by a rotating boom. This is not specified in the standard and there is no obvious reason why a manually moving microphone following the correct traverse should give different results.

The two techniques were compared in the joint IoA / RDL Round Robin test [2] and no significant difference was found. The Guide therefore allows testers to use either fixed or moving microphone techniques. The joint ANC/RDL/BRE research project is currently investigating the effect of the additional acoustic absorption in the source room as a result of the presence of the tester holding the microphone, and if a significant difference is found the Guide will include a correction for this.

5.5 Averaging

There has been considerable confusion over averaging of sound pressure levels and level differences, and ISO 140 is not very clear on the latter point. The requirements and procedures are, however, described very clearly in Annex B of Approved Document E. There are two separate averaging processes : i) averaging measured levels at different microphone positions in a room, which is done on an energy basis, and ii) averaging the level differences between rooms, which is done arithmetically. Using fixed microphone positions and a single loudspeaker the averaging procedure is as follows :

1. Place the loudspeaker at the first location.
2. Measure the source room level at each of the 5 microphone positions. Average the results on an energy basis (correcting for background noise as required)
3. Measure the receiver room level at each of the 5 microphone positions.
4. We now have source and receiver room levels for loudspeaker position 1. Subtract them to give the level difference in each 1/3 octave band for loudspeaker position 1.
5. Move the loudspeaker and repeat steps 2-4 for loudspeaker location 2. This gives the level difference in each 1/3 octave band for loudspeaker position 2.
6. Average the two level differences arithmetically. This gives the average level difference D in each 1/3 octave band.

Using a moving microphone simplifies matters because there is no need for energy-averaging between microphone positions. A 30-second microphone "sweep" has the effect of both space-averaging and time-averaging, and is equivalent to five 6-second measurements at fixed microphone positions. Because all measurements are in terms of Leq the time-averaging is automatically on an energy basis.

As an additional source of confusion, some sound level meter manufacturers supplied (and in some cases some still supply) software that averages the sound level differences on an energy basis. However, using two loudspeakers simultaneously (with separate uncorrelated sources) allows the use of only a single measurement in each room. This eliminates the need to average level differences. However, we encourage testers to write spreadsheets for processing the results, as this ensures familiarity with the standards and procedures as well assisting in more detailed analysis. We find that "black box" calculation solutions are not conducive to a good understanding of the underlying principles.

5.6 Background noise corrections

Both parts 4 and 7 of ISO 140 set out procedures for correcting the receiver room levels for background noise. Where the background noise (measured as Leq) is between 6 and 10 dB below the receiver room level the correction is, as one would expect, based on a logarithmic subtraction of the two. Where the difference is 6 dB or less, however, a correction of 1.3 dB (corresponding to a difference of 6 dB) must be used. This is of course technically incorrect but is necessary to avoid nonsensical results where the background noise is very close to (or even higher than) the receiver room noise. This is possible because of course the background noise is measured either before or after the receiver room noise, and will vary with time.

Some applicants have assumed that every effort should be made to measure the lowest possible background noise level, whereas of course the purpose is to assess the effect that the background noise has on the receiver room level. The measurement technique for background noise should reflect this by being identical to the technique used for the receiver room measurement. This is not made clear in the standard.

5.7 Reverberation time measurement

There have been many long and heated discussions about the use of impulsive noise sources to measure RTs. Some testers use starter pistols and balloons in preference to the interrupted noise method, which requires a loudspeaker in the receiver room. This technique can be useful where mains power is unavailable in the receiver room, as sometimes occurs. Studies have shown that if anything, impulsive noise sources measured correctly give better reproducibility on RT results than interrupted noise [3]. However, impulsive sources have sometimes been rejected because ISO 140:4 implies – but does not specifically require – use of a loudspeaker as the source for the RT measurements.

Confusingly, ADE and ISO 140:4 both refer to BSEN ISO 354 “Measurement of sound absorption in a reverberation room” which is a standard for the assessment of absorption coefficients in laboratories. They do not refer to ISO 3382 [4] which is the widely-used standard describing methods of Reverberation Time measurement on site. This anomaly may reflect the composition of the committee which created ISO 140. In any case, both ISO 354 and 3382 allow the use of impulsive sources provided that the measurement system uses the Schroeder reverse-integration method (as nearly all measurement systems do).

BS EN ISO:140 Part 14:2004 “Guidelines for special situations in the field” further confuses the issue by stating that RT measurements should be carried out “as described in ISO 140-4 or ISO 3382-2.” This latter reference introduces a problem of causality as ISO 3382-2 “Acoustics – measurement of reverberation time - Part 2 Ordinary rooms" has not been published, although a draft was apparently issued for consultation in 2004. This has passed widely unnoticed, as indeed has ISO 140:14 itself [1], which in some respects contradicts ISO 140:4.

The continuing confusion over acoustics standards, and the apparent reluctance to consult the acoustics profession over relevant standards and legislation, provide another incentive for the ANC to issue its own guidance and clarification.

[1] The author is currently researching the consultation process for acoustics standards and would be interested to hear from readers of this paper who were aware of the existence of ISO 140:14, even in draft form, before September 2006.

6 REFERENCES

1. Sue Bird, "The Association of Noise Consultants' Registration Scheme for Pre-Completion Testing." Acoustics Bulletin, Vol 31 No 4, 2006
2. I C Critchley, P R Dunbavin **"**Joint ANC/RDL Round Robin on Uncertainty in Sound Insulation Measurements." Proc IoA Vol 29, Part 3, 2007.
3. A James, "Results of the NPL study into comparative room acoustic measurement techniques: Part 1, Reverberation time in large rooms" Proc IoA Vol 25 Part 4.
4. ISO 3382 :1997 "Measurement of reverberation time of rooms with reference to other acoustical parameters"

Acknowledgement: The Author is grateful to the Board, Examiners and Members of the Association of Noise Consultants' Registration Committee who have between them developed the principles and details of the Good Practice Guide for the ANC.

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